Repacking – Preparing Antennas, Combiners and Transmission Line

Daniel S Fallon
Dielectric, LLC
Raymond, Maine

Abstract – *The questions looming around repacking are usually; "When will it happen?" "What's the process?" "How does the re-imbursement work?" For the purpose of this paper, let us leap over all of the political uncertainties and take an in depth look at the RF equipment required for re-channelizing. This paper will look at the viability of re-use of RF components during the transition period and after the switch. Focusing mainly on RF systems, transmission line and antennas, the paper will analyze what equipment can be re-purposed or re-tuned and what needs to be replaced. The technical complications, impact on available space and tower loading along with the logistics of multiple transition scenarios will be investigated.*

INTRODUCTION

How much of my transmission equipment can be re-used on my new re-packed channel?

The answer to this question will depend more on the logistics of a nationwide repack than the bandwidth of the RF components in question.

The bandwidth and effort required to re-tune various RF components is simple to catalog. I will proceed to provide that information in general terms. The more difficult part will be getting qualified personnel to perform the re-tuning in the allotted amount of time. The paper will describe the amount of effort to retune an antenna, transmission line and RF system and describe the various scenario's where this may be feasible.

A stations RF system, transmission line and antenna are all composed of limited bandwidth parts. The two easiest components to categorize are the antenna and the mask filter. The short answer to the question for both of those is no, they cannot be re-used. A more nuanced answer will be given in the sections 1 and 2, devoted to these components. A broadcast RF system is composed of several components, some which are broadband and some which are intentionally narrowband. The RF system will be addressed in section 3.

Section 4 deals with the logistics of the re-pack. Unlike the analog to DTV transition there will be no simulcast period for the re-pack. The two options being considered are either a staged region by region transition or a full nation-wide flash cut to the new channels. The very nature of being on air with channel A today and channel B tomorrow makes the concept of re-use of RF components and transmission line impractical; if re-use is a goal then an interim transmission facility will be required.

1 - ANTENNAS

About 90% of the installed UHF antenna base in the US uses what is known as a pylon (or slotted coaxial) antenna. In spite of their advantages in cost, reliability and wind load, these antennas are inherently narrowband. If an antenna is "cut" for one channel then it may have acceptable performance on an adjacent channel, but no more. The key criteria for re-use are that an antenna must be center-fed and there must be sufficient headroom in the transmission line / RF system to handle considerably higher reflected power. An end-fed pylon will have excessive beam-tilt on a channel it is not designed for , even an adjacent channel. The beam tilt will change the coverage area and null-fill. If the antenna is center fed then the pattern may be acceptable but the match at the adjacent channels will degrade. An antenna with an optimized return loss of 35 dB on its intended channel can have a return loss as poor as 20 dB on an adjacent channel. The transmission line, RF system and transmitter would have to be able to run into such a poor match.

The match of the antenna on an adjacent channel can be checked from the ground using a network analyzer with a "TDR" function. If it appears to be a viable option to re-purpose a pylon antenna on an adjacent channel then this measurement should be performed.

Moving down in channel with a pylon of the same gain will mean a larger antenna. The larger antenna will mean more tower loading. To complicate things changes to towers have to be evaluated based on the TIA-222 rev G specification. This may or may not have significant impact on the tower as the analysis techniques are very different than rev F. In some states, but not all, new construction must comply with rev G. In addition tower construction may need local zoning permits. To make a well informed decision of whether to stay on an existing tower with a new antenna or to move to another tower or lease space on a panel antenna a structural analysis of the tower is required.

The repack may result in several co-market adjacent channel allocations. A good solution for these is to broadcast from the same antenna. Either a properly designed pylon or a panel antenna can support adjacent channel operation.

The remaining 10% of antennas currently deployed in the US are some sort of broadband antenna. The most prevalent of these will be the corporate fed panel antenna. These consist of several radiators which are fed from the main transmission line by a series of power dividers and phased transmission lines. Most of these panels are owned by "vertical real estate" companies and they lease the ability to broadcast from the panel to local stations. Moving to a panel antenna may be a viable option for a broadcaster either during the transition or post re-pack. The practical questions to be asked about joining an existing panel are (1) what is the pattern / coverage area (2) is there capacity on the existing antenna and transmission line (3) what changes are required to the channel combiner to accommodate the new channel. The good news is there may be a tenant leaving the panel because they have decided to sell in the auction so there may be capacity.

Co-location, either from the same antenna site or from a broadband antenna will help alleviate interference resulting from the more closely packed channel allotment post repack.

2 - TRANSMISSION LINE

Rigid coaxial transmission line may be able to be re-used if the new channel assignment is within the recommended channel set for the line length. Coaxial line comes in three lengths for TV use; 19½', 19 ¾' and 20'. Table 1 lists the recommended channels for each. If a station is currently operating on channel 44 with 20' line lengths then most likely the line can be re-used if they are re-packed to channel 23 but not if they are re-packed to channel 24. One caveat is elbow complexes may be tuned narrowband with a tuning ring soldered to the inner conductor. If this is the case the elbow with the ring may have to be replaced. Typically the elbow in a complex which has a ring soldered to the inner is marked with a black ring around the outer conductor.

Note that twenty foot line lengths can be used on most VHF channels. A run of rigid line of this length is one of the few RF components that can be re-used moving from UHF to VHF.

The recommendation for transmission line is to get a broadband sweep of the line. Using the TDR function a network analyzer can characterize a transmission line run over all of UHF. The sweep can identify elbow complexes that need to be re-tuned. If sweeps have been done and are filed – find them and study the possible channels the run can be used at. If sweeps of the line have not been done – have someone come and do them. There are a handful of consulting engineers that can do these sweeps, hire them now before they get really busy. This information will help you plan and budget the work required to get the transmission line ready for a new channel.

There are a few rigid line runs that are broadband – a run of digit line will use mixed line length to assure good broadband match. These line runs are generally only used to feed broadband panel antennas. The elbow complexes used in these runs usually have tunable elbows; the tuners can be accessed from the outside.

Recommended Line Lengths

Channel	20'	19¾'	19½'
2	•		
3	•		
4			
5	•		
6	•		
FM*			
7	•		
8	•		
9	•		
10			•
11	•		
12	•		
13	•		
14	•		
15	•		
16			•
17			•
18	•		
19	•		
20			•
21			•
22	•		
23	•		
24		•	
25			•
26			
27	•		
28	•		
29			•
30			•
31	•		
32	•		
33			•
34			•
35	•		

Channel	20'	19¾'	19½'
36	•		
37			•
38			•
39	•		
40	•		
41			•
42			•
43	•		
44	•		
45		•	
46			•
47	•		
48	•		
49		•	
50			•
51	•		
52	•		
53		•	
54			•
55	•		
56	•		
57		•	
58			•
59	•		
60	•		
61		•	
62			•
63	•		
64	•		
65		•	
66		•	
67	•		
68	•		
69		•	

* For full FM band operation 17 1/2' line sections are recommended. For single channel applications standard line lengths can be used.

TABLE 1 – COAXIAL TRANSMISSION LINE LENGTHS

Flex lines are another broadband transmission line. Facilities using air cable to feed their antenna will likely be able to re-use the cable on a new channel.

Gas barriers used to pressurize transmission line are broad-band; they can be used at any channel.

One positive aspect of moving down in frequency with coaxial transmission line is that the line loss is less. This may translate to a small savings in transmitter power.

For stations that have installed DTW or Andrews GLW waveguide transmission line there is possibility of re-use if the new channel falls in the guide bandwidth. Tables 2 and 3 detail the channel ranges of relevant DTW and GLW sizes. The transitions into and out of these guides will have to be re-tuned.

Recommended Line Lengths

Channel	DTW 1750A	DTW 1500A	DTW 1350A
14	143 5/8"		
15	143 5/8"		
16	138"		
17	138"		
18	143 5/8"		
19	143 5/8"		
20	143 5/8"		
21	138"		
22	138"		
23	143 5/8"		
24	143 5/8"		
25	143 5/8"	138"	
26	138"	143 5/8"	
27	138"	143 5/8"	
28	143 5/8"	143 5/8"	
29	143 5/8"	138"	
30	143 5/8"	138"	
31	138"	143 5/8"	
32	138"	143 5/8"	
33	143 5/8"	143 5/8"	
34	143 5/8"	138"	
35	143 5/8"	138"	
36	143 5/8"	143 5/8"	
37	138"	143 5/8"	143 5/8"
38	138"	138"	143 5/8"
39	143 5/8"	138"	138"
40	143 5/8"	143 5/8"	138"
41	143 5/8"	143 5/8"	143 5/8"
42	138"	143 5/8"	143 5/8"
43	138"	138"	143 5/8"
44	143 5/8"	138"	138"
45	143 5/8"	143 5/8"	138"
46	143 5/8"	143 5/8"	143 5/8"
47	143 5/8"	143 5/8"	143 5/8"
48		143 5/8"	143 5/8"
49		138"	138"
50		138"	138"
51		143 5/8"	143 5/8"

TABLE 3 – DIELECTRIC DTW LINE LENTHS

GUIDELine® Attenuation Ratings

Channel Number	Visual Carrier MHz	Attenuation dB/100 ft
GLW1750		
14	471.25	0.0521
15	477.25	0.0502
16	483.25	0.0484
17	489.25	0.0469
18	495.25	0.0454
19	501.25	0.0441
GLW1700		
20	507.25	0.0430
21	513.25	0.0419
22	519.25	0.0409
23	525.25	0.0399
GLW1750		
24	531.25	0.0391
25	537.25	0.0383
26	543.25	0.0375
27	549.25	0.0368
28	555.25	0.0362
29	561.25	0.0356
30	567.25	0.0350
31	573.25	0.0344
32	579.25	0.0339
33	585.25	0.0334
34	591.25	0.0330
35	597.25	0.0325
36	603.25	0.0321
37	609.25	0.0317
38	615.25	0.0314
39	621.25	0.0310
40	627.25	0.0307
41	633.25	0.0303

TABLE 2 – ANDREW GLW LINE LENGTHS

3 - RF SYSTEMS

Figure 1 shows a typical two tube RF system used for 30kW to 70 kW transmitters. Most of the components are waveguide. Waveguide used in RF systems come in three sizes; WR1800, WR1500 and WR1150. Their channel ranges, respectively, are ch 14-17, ch18-48, ch 44-69. The short take away from this list is that any station that is currently operating on a WR1150 RF system there will be no opportunity to re-tune the existing equipment to a re-packed channel.

WR1500 RF systems afford good opportunity to re-use several major components provided there is time scheduled for factory refurbishment. WR1800 systems are of such limited channel range that a station re-packed to these low channels will either have to buy new or find a station abandoning their transmission plant.

Referring to figure 1; there are several individual components in an RF system, some of which are broadband and some of which are not. The first item is the coax to waveguide transitions. The majority of these are cross-bar type and can only be tuned over a 4-5 channel range. The plan should be to replace these if moving down in channel.

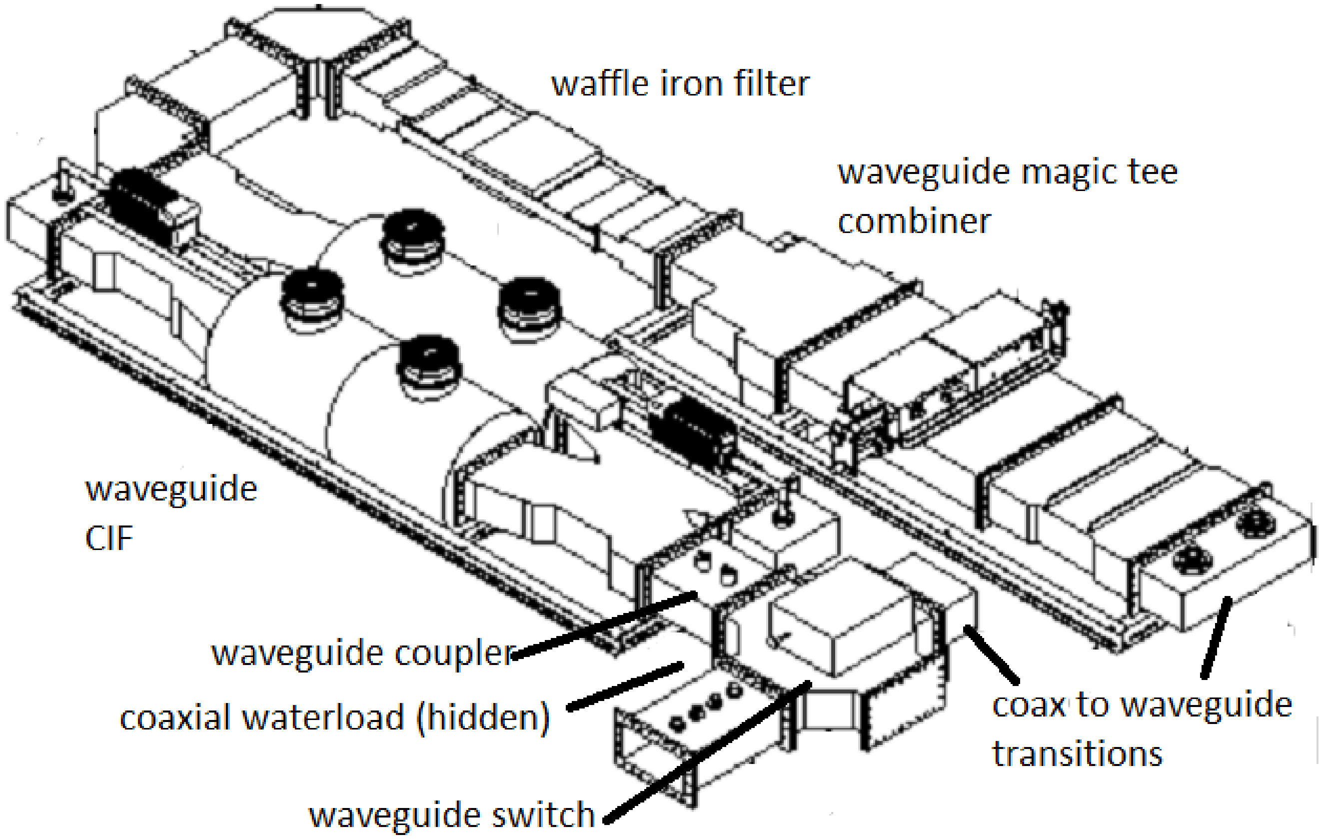

FIGURE I - HIGH POWER RF SYSTEM

The next component is the waveguide magic tee combiner. The WR1500 magic tee and phase shifters can be tuned over the entire WR1500 channel range (ch18-48). This tuning however is not an "in the field" exercise. The phase shifters may need new dielectric slabs to move several channels. A magic tee combiner that needs to change channel should be returned to the factory for complete optimization and refurbishment. The next component is the waffle iron filter. The WR1500 waffle iron is tunable from channels 18-43. Again factory refurbishment is recommended. The WR1500 H-plane miters are channelized into groups of 5 to 15 channels; these will have to be dealt with on a case by case basis.

The waveguide CIF is a channel specific item. The loads are the only part of the CIF that can surely be re-used. The hybrids, like the miters, are grouped into channel ranges of varying size. The filter cans are single channel. The best advice is to plan on replacing the entire CIF, except maybe the loads.

The waveguide directional coupler is broadband for the WR1500 channel range. It can be set to a new channel in the factory or in the field.

The coaxial water-load is tuned to specific channels. It can be re-tuned to any UHF channel but most loads in the field will require factory tuning. The WR1500 waveguide water-load is in the same category the load can be retuned but factory refurbishment is recommended as some component parts may need to change.

The waveguide switch is a broadband assembly but typically optimized to channel using tuning buttons. A switch can be returned to the factory for re-tuning at a new channel. Field re-tuning is possible.

Figure 2 shows a medium power RF system used for 10 kW to 25 kW transmitters. The components in this system use coaxial line rather than waveguide interconnect. This make them inherently broader band. The coaxial switch, fine matcher and the oil load are all wideband and require no tuning. The directional coupler can be set to any required coupling value at any UHF channel. This can be done either in the field or at the factory.

The mask filter shown in figure 2 is a reflective waveguide cavity filter with coaxial input and output. This style of filter cannot be re-tuned but will have to be replaced. If the RF system is in the frame style shown in figure 2 the frame may also need to be replaced as the switch height will change.

A commonly used coaxial line component not shown in figure 2 is the patch panel. Patch panels are broadband and should not require re-tuning to work at a new channel.

Coaxial low pass filters are commonly used either in the transmitter or RF system. These are often banded to provide good rejection at the second harmonic. A harmonic filter will likely have a good match at a lower channel but the second harmonic rejection will suffer. Re-use of a coaxial low pass filter will have to be evaluated on a case by case basis, measurement of the existing filter is the best guide.

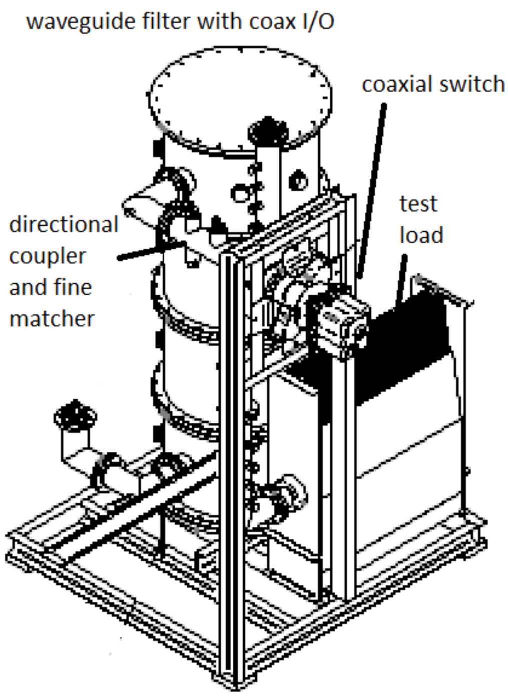

FIG 2 – MEDIUM POWER RF SYSTEM

4 - LOGISTICS

There are several unknowns about the re-pack that have significant impact on execution and logistics. The most important is the number of stations that will be changing channel. Most estimates place this number between 200 and 600 stations. The other is the timing – a three year window is currently written into the law. Most sources familiar with the details required to build new transmission facilities choose a more realistic number of 5-6 years.

One thing that is known is that there will not be a simulcast period like the DTV transition was. There will be some form of flash cut – either staged or nationwide. The most significant implication of this is that a new transmission facility must be ready before the switch over and the old facility must stay on air until the switch over. There are a handful of ways that this can be accomplished.

The first way would be to build a low power aux transmission site on the new channel. The intent would be to hit the cable head end and a good percentage of the current OTA market while modifications to the main transmission site were being done. The new site could be co-located with the current, using a side-mount on the current tower. The new site could be at a different tower as a side-mount antenna or as a tenant on a panel antenna. These decisions will most likely be driven by tower loading and cost. In either case the low power antenna could be used as a back-up after the full power construction is done.

If a side-mount on the same tower is used either a separate transmission line to the new antenna can be installed or, if the existing transmission line is suitable for both channels a tower top channel splitter could be employed to feed both antennas.

If the broadcaster is currently operating a two tube transmitter one option is to use a single tube (with a new mask filter) to feed the new antenna on the new channel. The other tube can then be re-tuned and the RF system refurbished after the transition date.

If the new low power transmission site were built at a different site than the main it could later function as a node in a single frequency network (SFN). Provided the timing issues are solved, it is likely that ATSC 3.0 will adopt a transmission scheme that supports SFN's.

With the low power transmission option the low power would go on air at the flash cut and then the current high power antenna could come down to be replaced with a new high power at the new channel. Any required tower work would happen at this phase as well.

The disadvantage of this option is the reduced coverage area for several months to a year while construction is underway on the new high power transmission system.

An option that does not have this dis-advantage is to build a full high power system on the new channel. This option may be practical for broadcasters that are currently operating on a side-mount or off a candelabra antenna. Another opportunity would be if a broadcaster in your market is abandoning a transmission facility that includes an intact tower. A full high power system could be built there, including a top mounted antenna.

Another option, if backup facilities already exist on the current channel is to begin broadcasting from the backup facility prior to the flash cut. The main facility could then be upgraded to the new channel and go on air on the transition date.

CONCLUSIONS

It is likely that some combination of all of these options will be exercised by broadcasters at they decide based on their local situation. As construction proceeds the most likely bottleneck will be the availability of qualified crews to perform the tower work. One estimate is that 30% of the broadcast tower inventory will need work to comply with the TIA-222 rev G code. The tower crews are required to do this upgrade work as well as take old antennas down and put new antennas and transmission line up.

Capacity in the broadcast transmission supply chain is a second consideration. All companies involved in supplying the DTV transition have down sized considerably since then. They certainly can grow to deal with new demand; this is not an instantaneous process though.

Due to the case by case nature of upgrades and changes to various broadcasters transmission facilities there is not a cookie cutter approach to the transition. For that reason alone, disregarding the shortage of qualified labor, a realistic estimate of the transition period is five to six years, not three.

REFERENCES

[1] Dielectric Transmission Line Catalog

[2] Andrew Corp, catalog 38.