Technical Advisory Report to the Jefferson County Planning Commission

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September 21, 2001

Overview

I have studied the following reports concerning development of a DTV transmitting facility at Eldorado Mountain:

a. Letter from Joseph P. Benkert to Susan Wood, Planner, Planning and Zoning Dept, Jeff Co, Re: Application for Rezoning and Exemption from Platting (Case Nos. 00015485RZP1 and 00015485EXP1), the original application from PTI with supporting materials.
b. NIST Technical Note 1519 and NTIA Report 01-387, Predicted and Measured Field Strengths in the Boulder, Colorado Area from Two Proposed Terrestrial Digital Television Tower Sites, Christopher L. Holloway, Frank H. Sanders, and Paul M. McKenna, 5/01.
c. Letter from Joseph P. Benkert to Susan Wood, Planner, Planning and Zoning Dept, Jeff Co, Re: Application for Rezoning and Exemption from Platting (Case Nos. 00015485RZP1 and 00015485EXP1) with 13 attachments, a response to the staff and community comments on the original application, 5/30/01.
d. Letter from Joseph P. Benkert to James Hart, 5/25/01, "Eldorado Rezoning Application" discussing a new Dielectric antenna pattern.
e. Engineering Report to Jefferson County on Eldorado Mountain site NIER Calculations and Quite Zone Calculations, 8/01.
f. Letter from Ernest K. Smith to City and County of Boulder, 8/3/01, Subject: Perusal of texts on the Eldorado Mountain Proposal by PTI, the Holloway etal. Report and associate letters. Part II.
g. Engineering Statement: Comments Concerning Hartech Report, by Raines Engineering, 8/27/01.
h. Engineering Report fro Jeff. Co. Colorado, Hartech Responses to Dr. Raines/s Statement dated 8/27/01 Regarding the Table Mountain Quiet Zone Calculations, 8/29/01.

It is my opinion that, from a technological point of view, there are problems guaranteeing protection of the Table Mountain Quiet Zone and with shadowing and multipath in Douglas County from a transmitter facility on Eldorado Mountain. There are also problems with shadowing and multipath in Boulder County, but not with protection of the Quiet Zone, from a transmitter facility on Squaw Mountain. All of these problems can probably be fixed with repeaters (shadowing and multipath) and directional antennas (protection of the Quiet Zone). However, presentation of a few details of these solutions are needed in order to appreciate their complexity.

Multipath, shadowing, and repeaters

Multipath is a problem in analog systems that create "ghosting" in the picture. This is also a problem in digital systems. Problems with multipath can be overcome with digital signal processing techniques. The discussion in the NIST report concerning indoor antennas (page 37)

can be applied to a multipath environment in general, i.e., either indoor antennas or outdoor antennas with no line of sight reception. Line of sight reception is always preferred whether it be from repeaters or the source transmitter directly.

Shadowing is the blockage of electromagnetic waves by natural or manmade structures. The most prominent of these structures in the state of Colorado are mountains. Shadowing only allows diffracted (the radiation actually goes around the object to some extent) and multipath (the radiation is reflected off of other objects) signals to reach the receiver. A standard "fix" for this problem is the use of repeaters. Repeaters collect line of sight radiation by placing a receiver with its antenna on an object (mountain, ridge line, tall building, etc.) in the line of sight of the transmitting radio or TV station. It then electronically processes and re-transmits the information at the same frequency (on-channel) or at a different frequency or channel to the shadowed area.

As for Digital TV repeaters, from the 1999 Broadcast Engineering Conference Proceedings report, "On-Channel Repeaters for Digital Television – Implementation and Field Testing" by Husak, Einolf and Salamon, the conclusions are that "The On-Channel Repeater works in a terrain isolated scenario" and "great care must be exercised in the design and implementation in order for the repeater to effectively retransmit a DTV signal." I believe that, with this technology, the shadowing problem in the Boulder area from transmissions from Squaw Mountain could be addressed. Likewise, the shadowing problem in the Douglas County area from a transmitter located at Eldorado Mountain can also be addressed.

Notching to protect the quiet zone

Notching is a solution to reduce emissions from an antenna in a specific direction. However, the depth of the notch alone cannot be used as a measure of its effectiveness; one must consider the depth over a finite notch width. To provide an example, consider the Dielectric antenna proposed by Pinnacle Towers, Inc. (PTI) in the letter of 7/25/01 from Joseph P. Benkert to James Hart that states that the antenna "will provide 30 dB of suppression toward the Quiet Zone..." The 30 dB of suppression is just 0.1 dB less than required for Channels 20, 31 and 59 and greater than that required of all other channels as stated in "Engineering Report to Jefferson County on Eldorado Mountain Site: NIER Calculations and Quiet Zone Calculations" prepared by James W. Hart, P.E. of Hartech, Inc. (henceforth referred to as the Hartech Report). However, the notch in the Dielectric antenna appears to be narrower than that of the antenna used in the Hartech Report. In the Hartech Report, it was calculated that a 7° notch was needed to cover the Quiet Zone (see Exhibit 5 of that report). A close look at the "Tabulation of Azimuth Pattern" from the letter of 7/25/01 reveals that the null is at 8°; at 5° the field factor is 0.123 (-18.2 dB) and at 11° the field factor is 0.155 (-16.2 dB). This is a 6° notch width where the highest field factor is 0.155 (-16.2 dB). The Hartech Report, with reference to Exhibit 6 uses the highest azimuth field factor as supplied by Richard Tell Associates, Inc. (RTIA) over the 7° notch width that is required. For Channel 20 this field factor is –20 dB, which is 3.8 dB lower than the Dielectric antenna. From this standpoint, the Dielectric antenna is actually worse than the one used in the Hartech Report.

There are other factors to consider when dealing with the issue of antenna patterns. Antenna patterns change with frequency. That is, depending on the characteristics of the antenna, the notch may appear at different angles at different frequencies. The width of the notch may also change with frequency. If the antenna is used for only one station, the variations have to be considered over a 6 MHz bandwidth. This is a fairly narrow bandwidth for the frequencies

considered for TV Broadcast channels so that the antenna pattern probably will not vary significantly over the bandwidth. However, if a single antenna is used for a number of stations (as proposed by PTI), the antenna pattern could vary substantially depending on the total bandwidth. This issue is addressed with respect on one type of antenna, the Kathrein antenna, in the Engineering Report of Mullaney Engineering and Raines Engineering (henceforth referred to as the Mullaney/Raines Report). In that report, a number of polar antenna patterns were supplied (corresponding to different antennas) that may provide a suitable notch (both depth and width) over a frequency band that includes two VHF stations and as many as 4 UHF stations for each single antenna. I say, "may provide a suitable notch" because the polar plots of the antenna patters do not provide enough resolution to make that determination; tabulations would provide the needed detail.

However, there are still more considerations. Antenna patterns provided by manufacturers are measured in a very controlled environment that simulates free space. It is as if the antenna where in the Universe all by itself. There are no reflections in the manufacturers' measuring environment. The antenna pattern of the antenna located on a tower at Eldorado Mountain will differ from the antenna pattern of the same antenna located on Squaw Mountain. Both patterns will differ from the manufacturer's measured antenna pattern. Both patterns will also change with distance from the antenna because of the multipath problem.

There have also been many discussions from engineers with NIST, Hartech, Inc., RTAI, PTI, and Earnest K. Smith, as to the predictions of field levels in the Quiet Zone; in some cases there were arguments over levels differing by as little as 0.5 dB. The prediction techniques used result in, well, predictions. From the documents I received, there were no statistical studies done and no confidence levels stated with respect to these predictions. The values cannot be taken as fact. The only way that the actual field levels can be determined is by testing. Testing was done by engineers from NIST with a transmitting antenna at Eldorado Mountain and a receiving antenna at the Quiet Zone. However, the test was not done using a transmitting antenna at the same height as the proposed transmitting antenna. Height of antenna above the ground level can have a significant effect on received signal levels, especially when the terrain is irregular. The testing was done primarily to validate a prediction model. This method probably yields the best prediction, but again, no confidence levels or bounds on the levels expected in the Quiet Zone are stated.

The point of this extended discussion is that in addition to the fact that each antenna must be evaluated for both depth and width of the notch in order to determine its effectiveness, actual testing will be the only way to determine if the requirements for protecting the Quiet Zone are met. This can be summed up by a statement[1] made in a report by Raines Engineering, "Engineering Statement: Comments concerning Hartech Report" dated August 27, 2001. "PTI commissioned preliminary designs for DTV antennas to meet the requirements for protecting the Quiet Zone, and the resultant antenna patterns included in the Mullaney-Raines report were developed by Kathrein Antennen-Electronic. *For DTV broadcasts, the designs provide adequate protection to the Quiet Zone, and are achievable given the current state of antenna design technology.* Upon rezoning, a more extensive design process, including range testing for prototype antennas will be completed prior to the manufacture of the final version. Such further design work will be necessary so that Kathrein can provide the performance guarantees PTI will

[1] The quote is given in full here. The italicized text is a statement still being disputed.

require before purchasing these very expensive antennas. If the antennas do not adequately protect the Quiet Zone, the FCC, which has jurisdiction over such matters will require modification of the antennas before PTI's customers can operate with them."

Conclusion

The discussions above should convey to the reader that there are problems with locating DTV transmitters on both Squaw Mountain and Eldorado Mountain. The cited studies indicate that the technology exists to overcome these problems by using repeaters (in the case of Squaw Mountain) and directional antennas (in the case of Eldorado Mountain). It is my opinion that the answer to the question, "Which site is better?" will have to come from considerations other than those of technology.