BINAURAL PRESENTATION OF SSB AND CW SIGNALS RECEIVED ON A PAIR OF ANTENNAS

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A typical amateur receiving system consists of an antenna, a receiver to amplify and convert the RF signals to audio, and monaural headphones to present the audio to the listener. This system may be compared with a monophonic audio system consisting of a single microphone, amplifier and monaural headphones. These systems do not take advantage of human binaural hearing. Now consider a recording of a symphony orchestra from a signal-to-noise ratio standpoint. For simplicity, assume that each instrument in the orchestra contributes equal power to the total sound output, and that the cello section has one tenth of the total number of instruments in the orchestra. The output of the cello section is thus 10 dB below the total output power. A classical cellist might well consider the cello section the "signal" and all of the other instruments "noise." While listening to a good stereo recording, he is able to concentrate on and hear the cellists, even though the "signal-to-noise" ratio is -10 dB!

It is relatively simple to convert a monaural audio system to stereo--a second microphone and amplifier are added and stereo headphones are used. The same approach may be applied to a CW and SSB receiver system, as shown in figure 1. A second antenna is added, a second receiver amplifies and converts the RF signals to audio, and the outputs of the two receivers are fed to stereo headphones. There are two difficulties to overcome. According to reference 1, binaural hearing uses relative amplitude, phase, and time delay information between the two ears to determine the position of a source and allow the listener to concentrate on that particular direction. The relative amplitude requirement is satisfied by using two receivers with equal gain and no AGC. The relative phase requirement may be met by locking all of the oscillators in each receiver to a common standard, or more simply by using only one set of oscillators for both receivers. Any relative time delay is preserved along with the relative phase.

EXPERIMENTS

The first tests were conducted in 1980 using the apparatus shown in figure 2. Two LM1496 product detectors

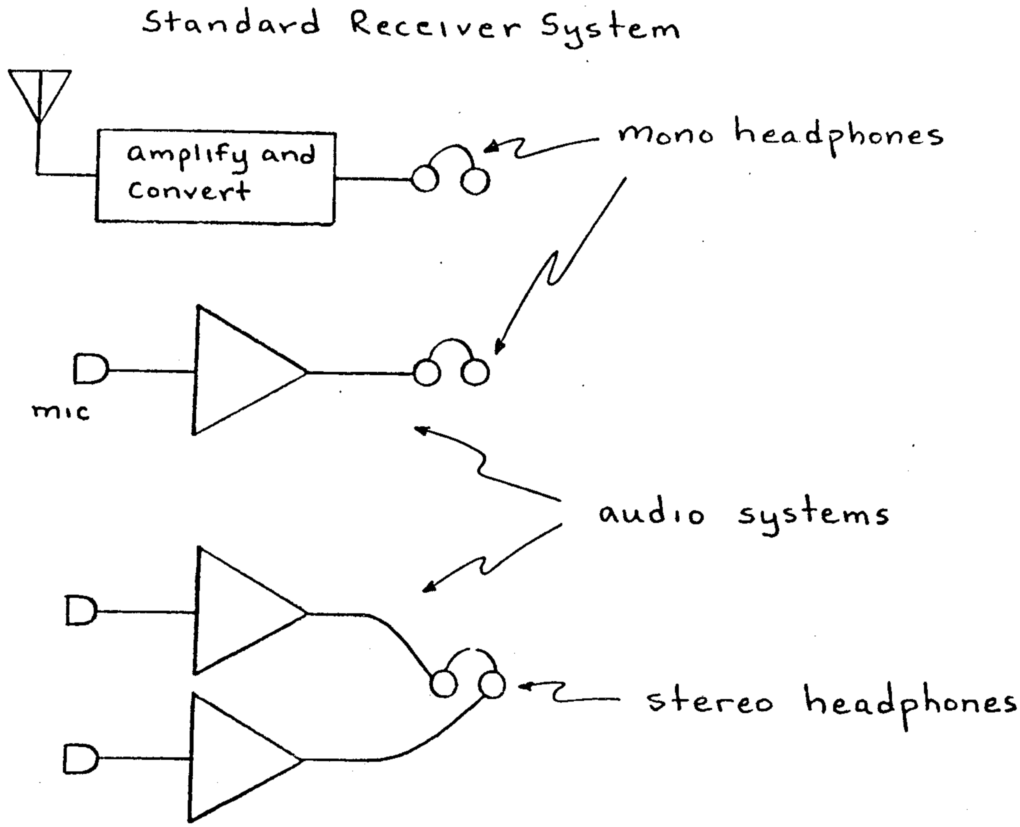


Figure 1

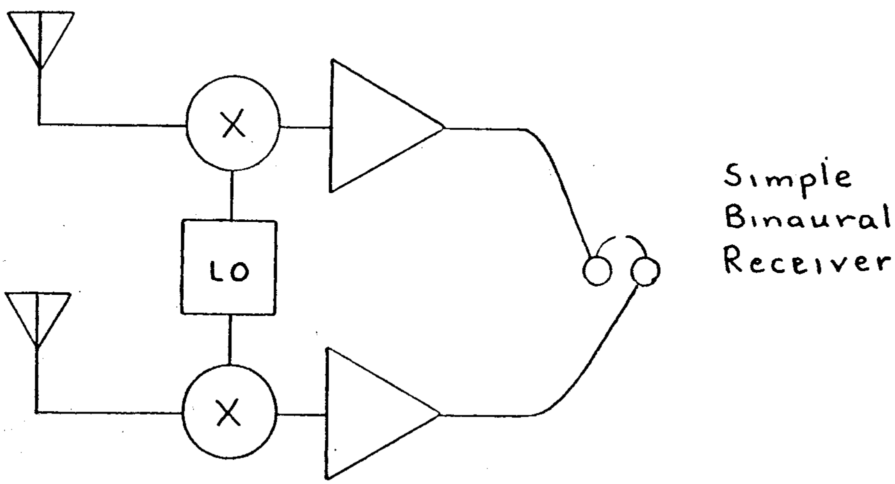


Figure 2

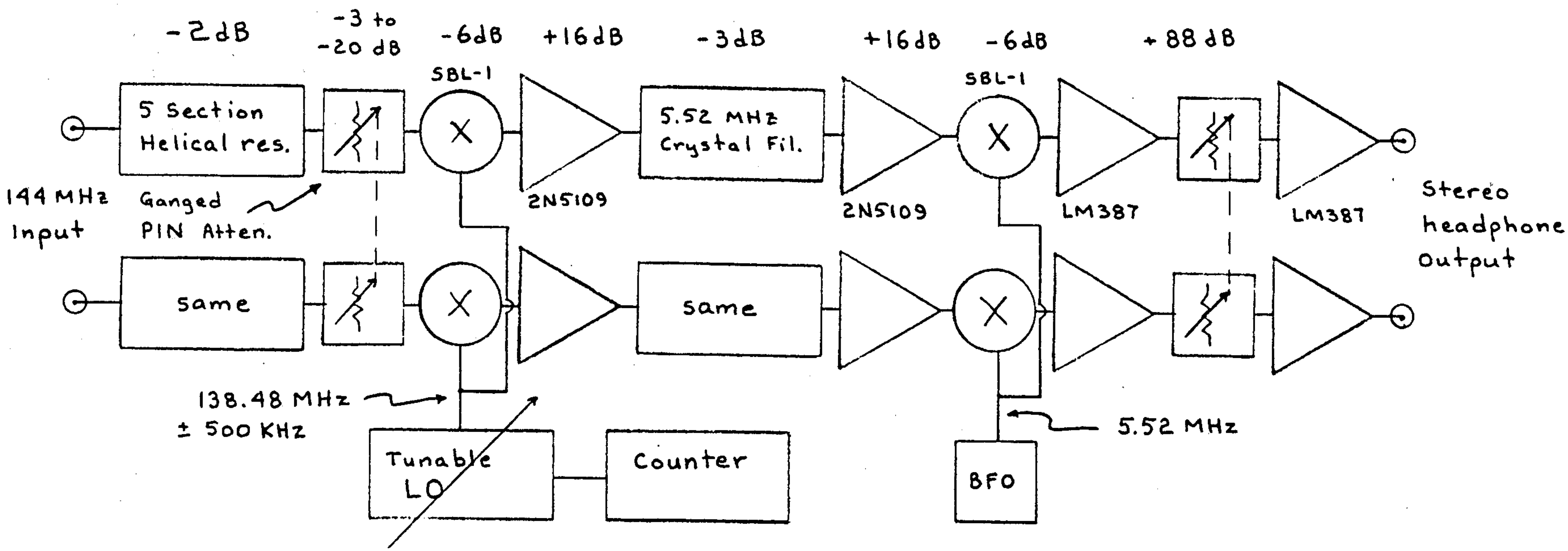
were built on a "superstrip" breadboard. The LO was a URM25 signal generator, the outputs of the two product detectors were fed to the microphone inputs of a Technics RS686 stereo cassette tape deck, and two 20 foot pieces of wire were used as antennas, connected directly to the inputs of the product detectors. The resulting binaural audio output exhibits the same qualities as a stereo audio recording, with a perceived space and each signal at a different location. The ability to concentrate on a weak signal below the noise level is greatly enhanced. It was originally supposed that the antennas would have to be widely separated to obtain a space diversity effect. With the binaural output, however, phase differences between input signals arriving from different directions provide a sense of space even when the antennas are closely spaced. Tests in 1983 on 20 m using short wire antennas indicate that the perceived binaural space is present until the antennas are closer than one tenth wavelength. To maximize the phase differences between signals arriving from different azimuth directions, a horizontal antenna spacing of about one half to one wavelength is indicated. The antenna spacing required to achieve a binaural advantage does not appear to be at all critical. Spacing may thus be optimized tor transmitting pattern or mechanical constraints without compromising binaural receiver performance.

The simple receiver system in figure 1 exhibits the several problems commonly associated with direct conversion receivers--hum, microphonics, and twice the bandwidth of an equivalent superheterodyne SSB receiver. The binaural output puts it in a class by itself, however, and after an hour of listening to 40 meters in stereo I would no more be satisfied with the best commercial HF rig currently available than with a 1958 mono "HiFi" driving a 4" unenclosed speaker.

AN IMPROVED SYSTEM

During 1981 and 1982 the 144 MHz binaural SSB-CW receiver shown in block diagram form in figure 3 was designed and constructed using modern high dynamic range techniques. Since AGC is not needed, the gain distribution is somewhat different than current practice, with most of the gain obtained at audio using LM387 low noise stereo preamplifier IC's. 144 MHz was chosen as a compromise IF for up conversion from HF, down conversion from UHF and direct use on 2 m. The noise figure of the basic receiver is about 14 dB. When used on 2 m, a matched pair of Q-bit preamplifiers with 25 dB gain reduces the system noise figure to 1.6 dB. The noise figure on the other bands depends on the converters used.

This receiver has been used during the past two years



2 m Binaural SSB-CW Receiver/IF

Figure 3

as an upconversion IF for binaural listening on all of the HF amateur bands, as part of the 2 m station at KK7B, and as a downconversion IF from 432 and 1296 with additional circuitry for coherent propagation experiments. In every instance, binaural audio output has provided improved intelligibility for weak signals. Subjectively, the ability to dig through white noise, which seems to come from all directions, and interfering signals, ignition noise and static crashes which seem to come from specific directions, adds a new dimension to weak signal work, akin to looking for crickets on a warm summer night. On 2 m, the first impression is that the noise is louder, since it seems to come from all directions. When a signal appears to come from a single direction, however, it is possible to ignore most of the noise and copy the signal. The experience at KK7B has been that if I can tell something is there (tunable noise) with the monaural system using the same pair of antennas and preamp noise figure, I can copy about 90% with the binaural system.

Figure 4 shows the present 2 m system in use at KK7B. For normal operation, where the benefits of AGC and transceive frequency control are useful, the binaural receiver is switched out of the system. When the binaural system is on, relays K1A and K1B become the transmit-receive relays, and the binaural receiver operates during receive and the conventional transceiver-amplifier operates during transmit. The antennas are 6 element yagis vertically spaced 0.75 wavelengths.

Figure 5 shows some suggested antennas for binaural operation using various amateur bands and modes. Of particular interest is the meteor scatter array, which provides an optimized receiver for each ping, once the brain is accustomed to listening for a signal arriving from a different direction each time.

SOME RELATED ACOUSTIC EXPERIMENTS

The references provide a basic source for binaural phenomena information. The text by Kryter contains an additional bibliography with 914 references on human hearing in noise. According to Kryter (p. 41), the maximum advantage obtained when a signal and interference are each of equal strength in both ears, but oppositely phased, is 16 dB relative to monaural presentation of both signals. According to reference 3, the effective signal-to-noise ratio improvement for speech in the presence of randomly phased white noise is about 2 dB. Thus the expected improvement in effective signal to noise ratio obtained by using a binaural receiver instead of just combining the outputs of the two receive antennas is expected to be somewhere between 2 and 16 dB, depending on the nature of the interfering signal.

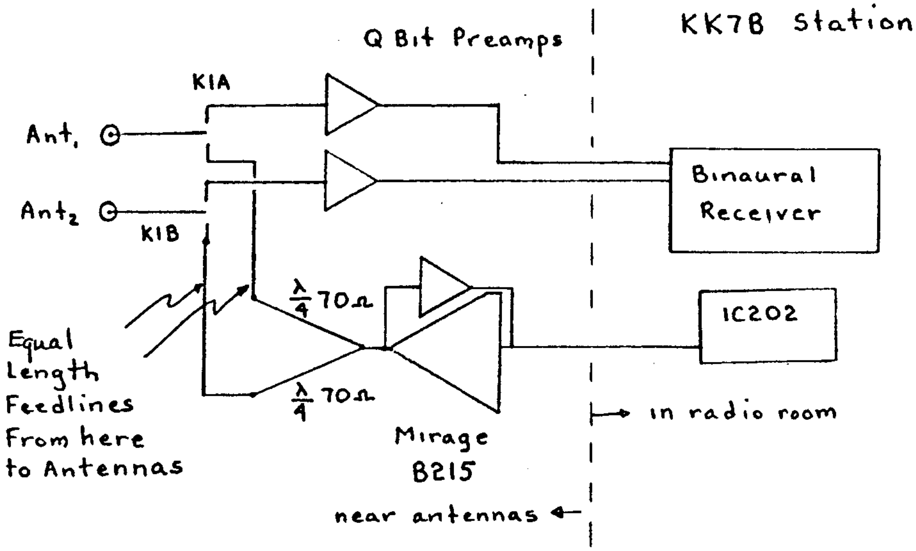


Figure 4

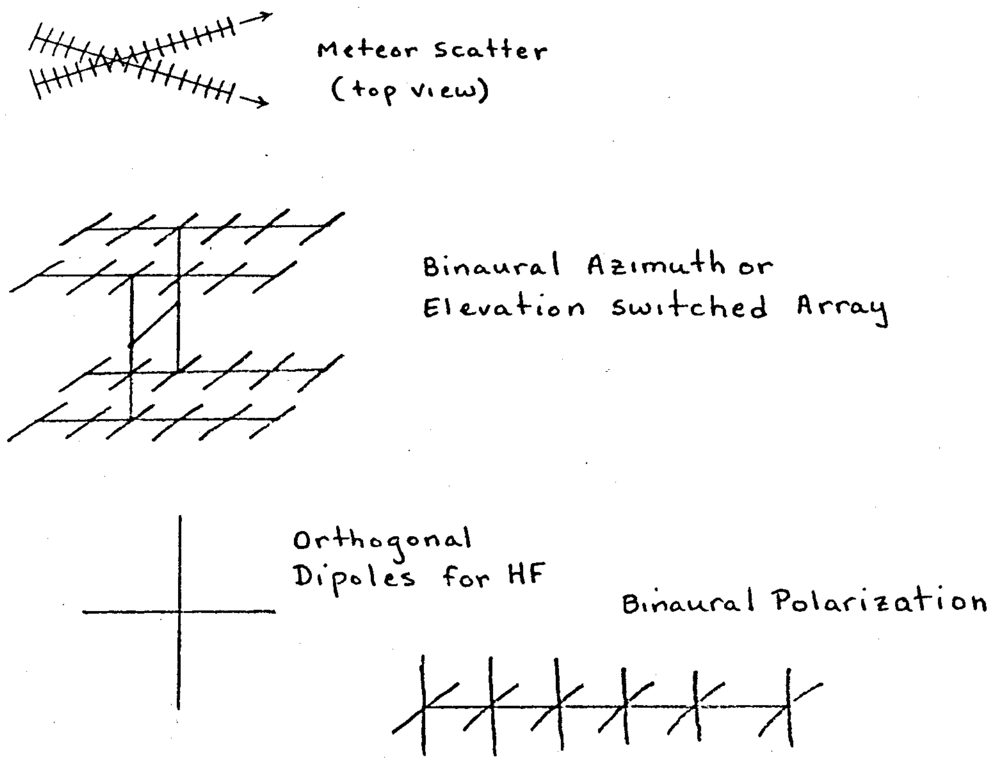


Figure 5

CONCLUSIONS

A theoretical approach to optimization of binaural communications systems (Reference 4) indicates that binaural reception provides the maximum advantage when the angle of arrival and/or polarization of the desired signal is variable, and the angle of arrival of interference is variable and unknown. These conditions apply to many of the interesting VHF-UHF propagation modes involving scatter from moving targets such as the moon, airplanes, meteors and patches of intense ionization. Particularly in the case of meteor scatter, amateurs have had to use antennas with less directivity in order to provide better "aperture to medium coupling." Another situation in which binaural reception is optimum is the early hours of a VHF contest, when multiple contacts are made in less than one beam rotation time in the presence of interference arriving from random directions.

Binaural reception allows the amateur to make better use of human hearing--the best analog weak signal processing system currently available. This is one area where amateurs may make a significant contribution, since it is uniquely suited to our peculiar communications needs and is inexpensive to implement.

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