KA7OEI's blog

*Random musings - usually on a technical (nerdy) subject - perhaps related to amateur radio and things found at **ka7oei.com** and **modulatedlight.org***

Sunday, November 17, 2019

Homebrew construction of 2 and 4 port splitters/combiners for the LF-MF-HF(30 kHz-30 MHz) frequency range.

Note:

This is a follow-up of a previous article, **"Characterizing the Mini-Circuits ZFSC-4-3, ZFDC-20-3, ZFSC-4-1-BNC+ and ZFSC-2-1+ well below their designed frequency range" - *link***.

Comment:

> All of the devices described here could also be used to combine signals from multiple sources. Unless the signals being combined are "phase coherent" *(e.g. from the same signal source)* the insertion loss will be the same as that in splitter operation.

"Rolling your own" splitter for LF through HF (<30kHz-30MHz):

Unless you get the Mini-Circuits devices for cheap at a swap meet or via a surplus outlet, their cost may be a bit prohibitive for casual use in the shack. How about making your own splitter that will work over the 30 kHz-30 MHz range?

Why would one want this? There are a number of modern Web-Based SDR receivers that cover from *(literally!)* audio through 30 MHz - and in my case, I have a number of ***KiwiSDR receivers - link*** that are connected to an antenna system that is capable of intercepting signals over this range. If one has several such receivers, it can be a challenge to find a splitter that works well over this range - particularly the low end - as described in the article linked above.

To do this, ferrite - rather than iron-powder - cores would be used, the most common types using mix 31, 43, 61, 73 and 75 - and the most useful of the lot for the low-frequency end are types 73 and 75. Not having a complete assortment of the ferrite types on hand, I used what I had and the use of a binocular core with mix 43 and a ferrite with mix 75 is discussed here.

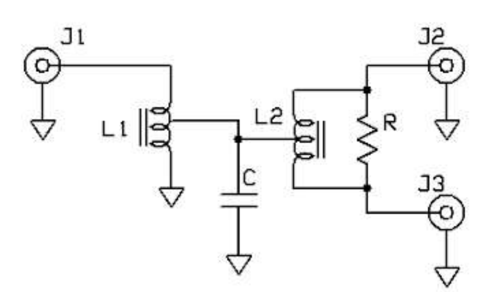

Figure 1:
A two-transformer splitter/combiner. L1 transforms the impedance at J1 to half that value and L2 splits the signal itself. R is twice the system impedance - 100 ohms in a 50 ohm system. The tap on L1 is at 0.707 times of the total number of turns: A tap at 7 of 10 total turns is "close enough" while C is a high-frequency compensating capacitor. L2 is a bifilar-wound transformer with the two sets of windings connected in series at the common point.
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Two-transformer splitter/combiner:

A common splitter topology consists of two cores: One to transform the impedance to half that of the characteristic system impedance and a second to split the signal two ways as depicted in Figure 1. The inductance of L1 and L2 should be high enough to present a reactance of 3-10 times the system impedance at the lowest frequency.

Figure 2 shows a tested version of this transformer, the details noted in the caption. According to this diagram the insertion loss is a nominal 3-ish dB from 50 kHz to 1 MHz, dropping down to about 5 dB loss between 20 kHz and 10 MHz and nearly 6dB at 30 MHz. Capacitor "C" was made variable, adjusted for lowest loss, improving the highest end by a bit over 1dB, and its value measured.

For LF ***and*** HF use, this splitter is just "OK" - the loss being an extra 3dB at the high end of the spectrum: If preceded with amplification, this loss may be tolerable - but note that even the nominal 3dB loss of a 2-way splitter should be of concern at the higher HF bands as signals - and the natural noise floor - can be quite weak and additional loss can drop the receiver's noise floor below that, potentially causing the loss of reception of weaker signals.

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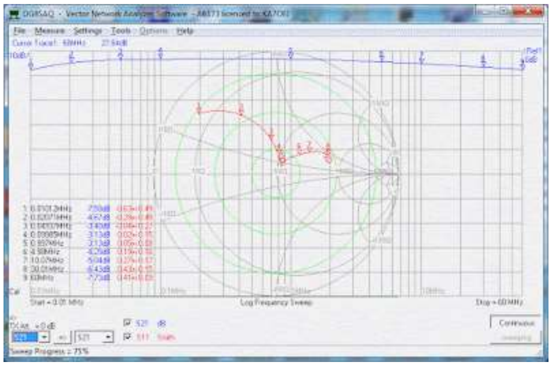

Figure 2:
Measured insertion loss of a transformer using two BN43-202 cores wound with 30 AWG wire: 10 turns, tapped at 7 turns for L1 and 10 bifilar turns for L2. R = 100 ohms and C = 62pF.
The required number of turns to achieve the desired low-frequency response increases the stray capacitance, undesirably increasing loss at the high-frequency end of the HF spectrum.
Click on the image for a larger version.

Much of the high-frequency loss is due to the inter-winding capacitance. Experimentally, versions were constructed using wire with PTFE *("Teflon")* insulation and comparing it with another with the same number of turns of the 30 AWG enamel and the losses for the PTFE wire version were 1.5-2dB lower - but fewer turns could be passed through the core and low-frequency response suffered.

If a higher-permeability material (like 73 or 75 mix) were used for the core rather than 43, fewer turns could have been used to maintain the inductance and low-frequency response and it is likely that the high-frequency loss would be reduced.

Single-transformer splitter-combiner:

Another common splitter/combiner is the form depicted in Figure 3, using a single core - and potentially this can reduce loss compared with a device with two cores.

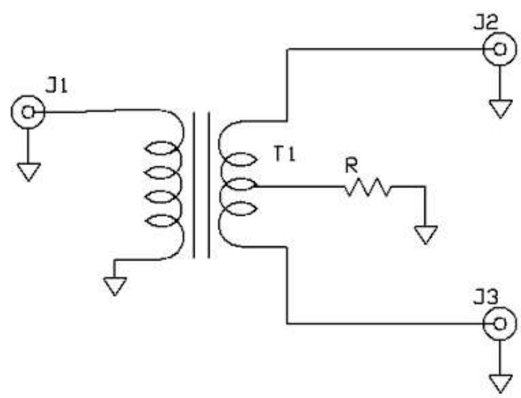

Figure 3:
In this form, the primary *(connected to J1)* has 1.414 times as many turns as each of the two identical secondary windings. The value of R is half that of the characteristic system impedance, or 25 ohms for a 50 ohm system: Parallel 51 ohm resistors were used for a nominal 25.5 ohms.
Typical turns values are 10/7 turns, 14/10 turns and 20/14 turns for the primary and bifilar secondary, respectively. For the center-tap, the windings of the secondary are connected as if they were in series.
Click on the image for a larger version.

In this system the primary should consists of 1.414 times *(e.g. the square root of two)* as many turns as each of the secondary windings.

Both a binocular and toroidal core were tried and better results were obtained with the FT50-75 core than the available BN43-202 binocular core - both because the higher permeability improved the low-end response and larger wire could be used for the toroid: Capacitance was reduced on the toroid because the turns could be spread out rather than being tightly overlaid as the case of the binocular core, and high-end losses were further-reduced by laying the turns of the secondary next to each other rather than the higher capacitance resulting from the two conductors being twisted as is commonly done with Bifilar windings.

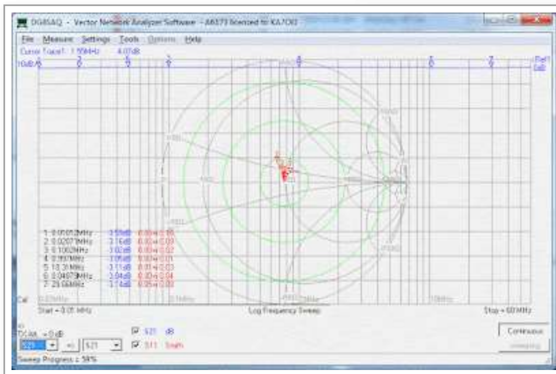

Figure 4:
The insertion loss of the described two-way splitter using 24 AWG wire on an FT50-75 core: It is well below 4dB over the range of 10 kHz to 60 MHz.
Click on the image for a larger version.

The results of this work are visible in Figure 4. For this transformer, two parallel secondary "bifilar" windings consisting of 14 turns each were carefully and neatly laid down using 24 AWG enamel wire with 20 turns of 24 AWG over the top. As can be seen, the results are excellent: The insertion loss is below 3.6dB from 10 kHz to 60 MHz and the overlaid Smith chart shows the VSWR to be pretty well-behaved, never exceeding 1.5:1 over this range.

Additional tests were run to determine the port-to-port isolation of this splitter - the results being visible in Figure 5. Over the range of 100 kHz through 60 MHz, the isolation exceeds 15dB, exceeding 25dB from abut 100 kHz through 30 MHz. During testing, the same device had been constructed using smaller 30 AWG wire and the results were worse above 10 MHz *(by 2dB at 30 MHz)* - likely a result of the skin effect losses of this smaller wire.

A four-way splitter:

I happened to have a need to take signals over a wide frequency range and split it four ways - specifically, to several KiwiSDR receivers, stand-alone web-based receivers capable of reception over the 5kHz-30MHz range - so I decided to construct a splitter using the configuration described above. To do this, I would need ***three*** splitters: A pair of splitters to feed the four outputs and one more splitter to feed the aforementioned two splitters.

- 12 volt supply
- 15 kHz low pass filter
- 160
- 1J18B
- 1J37B
- 1L6
- 1L6 substitute
- 1LA6
- 1R5
- 1Zh18B
- 1Zh37b
- 1Ж18Б
- 1Ж37Б
- 2 meters
- 2 watt amp
- 20 meter
- 20 meter filter
- 20 meters
- 2200
- 2200 meter band
- 2200 meters
- 222 MHz
- 23cm
- 24 GHz
- 24 volt
- 27 MHz
- 28 pin AVR
- 3-500Z
- 30.2 MHz
- 4 wheeler
- 40 meter
- 4000 meter band
- 4000 meters
- 4031
- 41 meter
- 4315b
- 5 volt supply
- 5/8" stud mount
- 50 ohm
- 6 meter beacon
- 6 meters
- 60 kHz
- 62-345
- 630
- 630 meter band
- 630 meter lowpass
- 630 meters
- 70 cm
- 70cm
- 75 ohm
- 75 ohm splitters in 50 ohm systems
- 8 bit A/D converter
- 8 pin AVR
- 80 meter QRM
- 80 meters
- 86730
- 87315
- A Battery
- A/D converter
- AB Battery
- AC
- AC filtering
- AC powerwall
- accuracy
- active antenna
- active filter
- active whip
- ad-1000
- ADC
- AGC

This splitter is depicted schematically in Figure 6:

This splitter consists of three of the two-way splitters connected as described: FT50-75 cores wound with 14 turns, each of two parallel 24 AWG conductors for the secondary overlaid with 20 turns of 24 AWG for the primary. During testing it was observed that the addition of capacitors "C" slightly reduced *(by nearly 1 dB)* the insertion loss at 30 MHz at the expense of increased loss *(about 2dB)* at 60 MHz - but because the target high-end limit was 30 MHz, this was considered to be acceptable.

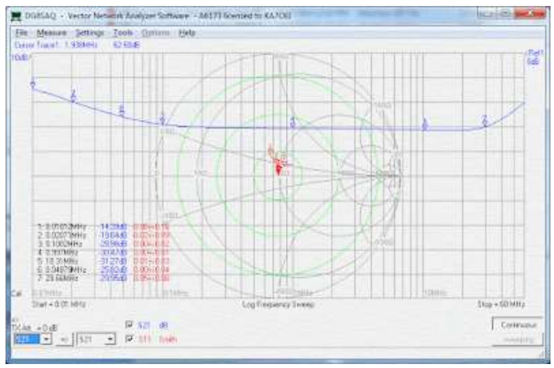

Figure 5:
The port-to-port isolation is quite good over the range of 100 kHz to 30 MHz. The peculiarly-flat isolation limit of the bottom "trough" of the graph is a result of the value of "R" not being exactly 1/2 of the impedance value of the system used for testing: If R is made variable, higher isolation may be obtained in the middle of the range - but the difference between that and the fixed resistors used was only an ohm or two. In practice, high values of isolation can be obtained only if the source and load impedances are ***purely*** resistive, but since practical antennas, amplifiers, receivers and filters will ***not*** be perfect sources and loads, such high isolation cannot be achieved in practice.
Click on the image for a larger version.

The end result was an insertion loss *(see Figure 7)* of less than 7 dB from 20 kHz through 30 MHz, rising to 8 dB and 9.3 dB at 10 kHz and 60 MHz, respectively, being under 6.3dB between 50 kHz and 10 MHz. In testing port-to-port isolation, the worst case results were those obtained from the same transformer *(e.g. T2 or T3)* and this value was at least 15dB from 50 kHz to 30 MHz.

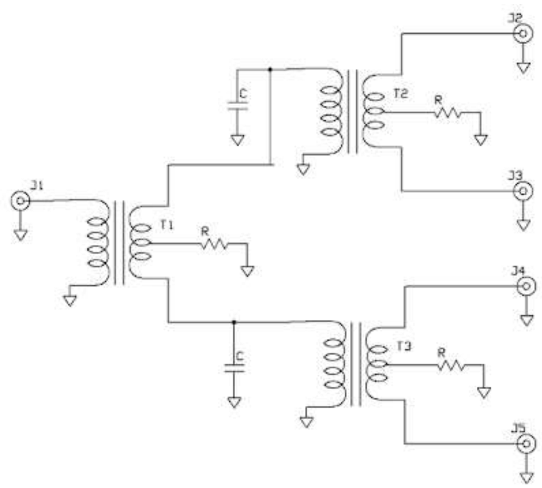

Figure 6:
For a 50 ohm system, resistors "R" are 25.5 ohms *(two 51 ohm resistors in parallel)* and capacitors "C" are 47pF NPO/C0G types used to "flatten" the response to 30 MHz.
The as-built splitter uses FT50-75 cores wound with 24 AWG, the dual secondary windings consisting of 14 turns and the primary with 20 turns.
The dual secondaries are laid parallel rather than twisted to minimize stray capacitance. The center-tap is connected as if the two secondary windings were placed in in series.
Click on the image for a larger version

This four-way splitter was built into a small die-case box for mechanical rigidity and electrical shielding. Inside the box, pieces of plastic tape were affixed to the bottom and the lid to eliminate the possibility of inadvertent shorting of connections to the case: Details of the mechanical construction may be see in Figure 8.

To reiterate: It was determined that with the number of turns required to obtain good response into the LF range *(e.g. below 30 kHz)* that the use of twisted bifilar windings was ***NOT*** indicated: Doing so resulted in excess loss *(3-6dB)* by the time one got to 30 MHz. As indicated, the use of thicker insulation *(e.g. PTFE versus enamel)* reduced this loss somewhat, but using the smallest wire on hand with the only available 75 mix toroid, too few turns could be wound to afford the needed inductance for the desired low frequency respons: The best-results with the materials on-hand were obtained by simply laying the "bifilar" windings parallel to each other. In this case, 24 AWG enamel wire was used, a compromise between lower skin-effect losses and the ability to fit the required number of turns on the FT-50 core.

Comment: There are other splitter topologies available that have their own sets of advantages and disadvanges. While some of these may be discussed in (a) future article(s), they are beyond the scope of this article - which is the construction of a very simple, straightforward device that is suitable for the task at hand.

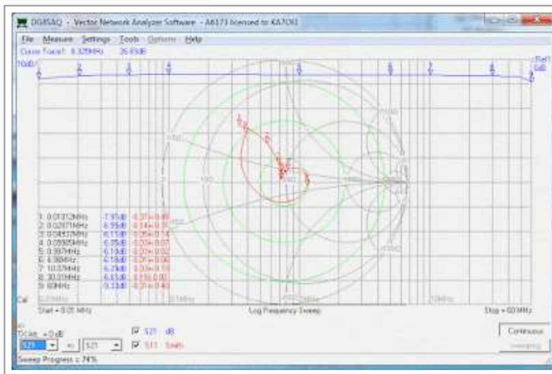

Figure 7:
This shows the typical insertion loss of the as-built four-way splitter depicted schematically in Figure 17. The insertion loss is less than 7 dB from at least 20 kHz through 30 MHz with the VSWR being 1.5:1 or less over that same range.
Click on the image for a larger version.

Conclusion:

If one needs a very wide-range splitter for broadband receivers that cover from LF through HF - such as some modern "Direct Sampling" SDRs *(e.g. the KiwiSDR)* there are some commercially-available devices that may be found that will work well - if you can find

- alignment
- all pass
- AM
- AM beacon
- AM broadcast
- am lowpass
- Amateur Radio
- amplifier
- amplitude modulator
- annular
- annular eclipse
- Antenna
- antenna gain
- antenna pattern analysis
- antenna support
- antenna switching for interference reduction
- AP
- APD
- APRS
- APT
- Arches National Park
- arcing
- arcs
- ardf
- Arduino
- ARGO
- ARRL
- ARRL Field Day
- atan
- atan2
- Atmel
- atomic clock
- ATS-3A
- attention-getting
- attenuation
- ATX
- audio delay
- audio filter
- audio hum filter
- audio low pass filter
- audio transformer
- auto tuner
- automatic volume tracker
- autotransformer
- Avalanche Photodiode
- AVR
- B Battery
- BA5SBA
- BA5SBA converter
- BA5SBA SDR dongle
- Baader
- back-up
- backpacking
- balanced line
- balanced modulator
- ballast interference
- balun
- balun designs
- band pass
- band reject filter
- band-pass
- band-reject
- bandpass
- bandpass band reject
- bandpass cavity
- bandpass filter
- bass response
- bat listener
- batter equalization
- battery

them surplus, or are willing to pay for them. If you are willing, a perfectly suitable device may be constructed inexpensive using a minimal complement of components.

Figure 8:
The as-built 4-way splitter. capable of useful operation from below 20 kHz to above 30 MHz. As described in the text, the cores are FT50-75 wound with 24 AWG wire, wired "dead bug" inside a small die-cast aluminum box. The resistors "R" and compensating capacitors "C" may be easily seen. The bottom of the box and the lid *(not visible)* are insulated with a piece of plastic tape - this this case, 1" *(25mm)* wide PET *(Polyester)* tape. If I'd had some on hand, I would have wound the transformers on slightly larger toroids to spread out the windings a bit.
Click on the image for a larger version.

* * *

This is a follow-up of a previous article, **"Characterizing the Mini-Circuits ZFSC-4-3, ZFDC-20-3, ZFSC-4-1-BNC+ and ZFSC-2-1+ well below their designed frequency range" - *link***.

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[End]

Posted by KA7OEI at 10:00 AM

Labels: BN43-202, combiner, directional coupler, FT50-75, HF, homebrew, insertion loss, KiwiSDR, lf, MF, mini circuits, Mini-Circuits, splitter, WebSDR

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- blink
- blink brake
- blinking
- blinking infrared led
- blinking LED flashing LED
- BN43-202
- bobbin
- Bodnar
- BOM
- bp/br
- brake light modulator
- breaker
- brick
- broadcast band
- BS170
- BSH12-N406L
- BT-168D
- buck converter
- buddipole
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- filament transformer
- fill factor
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- filtering
- filters
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- final transistor
- FIR Filter
- fishook
- fixing bricked RTL-SDR dongle
- flasher
- flashing infrared LED
- float charger
- floaty-thingie
- fluorescent interference
- fluorescent QRM
- flyback
- flyback transformer
- Flydog SDR
- FM
- FM transmit
- format change
- fox hunting
- fractional
- fractional phase adjustment
- free space
- free space optical communications
- free-space optical communication
- frequency lock
- frequency re-use
- frequency response
- frequency shift
- frequency stability
- frequency synthesis
- Friendship Cruise
- Fronius
- FSO
- FSO communications
- fst4
- fst4w
- FT-1000
- FT-1000 MP Mark V
- FT-530
- FT-757GXII
- FT-8
- ft-817
- FT50-75
- Fun Cube
- G20787
- GaAsFET
- GaAsFET preamp
- gaffer tripod
- gain
- gate current
- gate current amplifier
- GE Mastr II
- general purpose power supply
- generator

- service monitor
- shading
- shake light
- shake light power
- shake light transmitter
- shake powered transmitter
- shield
- shielded loop
- shielding
- shortwave spurious signal
- shunt regulator
- si-4031
- Si5351a
- signal
- signal booster
- signal level measurement
- signal meter
- signal strength
- sine
- sine generator
- sine wave
- sine wave inverter
- sine wave UPS
- single sideband
- Skyscan
- Skyscan 86715
- skyscan atomic clock
- skyscan bug
- Skyscan clock
- Skyscan clock not setting
- sm3
- smd
- smoke
- snap-on choke
- SocoTran
- Software Defined Radio
- Software Defined Transceiver
- solar
- Solar charge controller
- solar charger
- solar eclipse
- Solar Film
- Solar Filter
- solar panel
- solar power
- SolarEdge
- Solargraph
- solid state vibrator
- sound card
- source code
- SP-75
- spark gap
- spark gap transmitter
- speaker
- speaker limiter
- speaker protection
- speaker protector
- speaker rebuild
- spectran
- spectrum analyzer
- spectrum lab
- spectrum scope
- speech
- Speech Processor
- speedo
- speedo repair
- speedometer
- speedometer repair
- split transmit receive antennas
- splitter

- VNA
- voice coil
- volt-amps
- voltage converter
- voltage drop
- voltage monitor
- volume tracking
- volunteer monitor
- voter
- voting controller
- voting receiver
- voting receivers
- voting repeater
- VSWR
- W6POP
- W6QYY
- WA7ARK
- WA7X
- WA7X beacon
- warble
- wards airline
- waterfall
- waterfall display
- weak signal
- Weather Satellite
- WebSDR
- Wednesday Night Hike
- wheatstone
- whip antenna
- wideband
- WiFi
- winding
- winding machine
- wire size
- wireless router
- won't stop
- won't work
- woodpecker
- woofer rebuild
- word metronome
- wsjt-x
- WSPR
- WSPR beacon
- wsprd
- wsprdaemon
- WVNA
- WWV
- WWVB
- WWVB clock
- WWVB format
- WWVB simulator
- Yaesu
- Yaesu FT-530
- Z3801
- Zenith
- Zenith TransOceanic
- zero dropout regulator
- ZFDC-20-3
- ZFSC-2-1
- ZFSC-4-1
- ZFSC-4-3
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